

METHOD AND APPARATUS FOR ENHANCED PERFORMANCE

LIQUID CRYSTAL DISPLAYS

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CROSS-REFERENCE TO RELATED APPLICATIONS

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voltages are driven onto the pixel electrodes in a sequential scanning method to force transitions to a particular state, e.g. bright or dark. Often, several voltages are provided to the display at once to reduce addressing. These pixel driving voltages may be continuous (analog), as used by companies such as Colorado Microdisplay, Inc., or binary (digital), as used by companies such as DisplayTech, Inc. There are also hybrid approaches where a digital pixel value is used as a selector to multiplex global analog voltages onto pixel electrodes.

A drawback to prior addressing methods is that they limited the performance of the LCD. One common factor in prior addressing methods is that the overall display update interval was determined by the sum of the matrix addressing time and the worst-case electro-optical material transition time. Generally, the longer the addressing and transition times, the slower the performance of the pixels and the LCD.

Attempting to increase the performance of an LCD despite the fixed addressing and transition times decreased image fidelity and lead to a phenomenon termed temporal crosstalk. Typically, the worst-case electro-optical material time must be used to determine performance of the LCD because the data displayed on the LCD may not valid until the very last pixel element that was addressed has transitioned to its final state, e.g. to A or to B. If the display were allowed to be viewed before the last state transition has been completed, the viewer would perceive an blend of the new pixel state or brightness and the previous frame's or field's pixel state or brightness.

One possible approach to reduce temporal crosstalk is blank the display while addressing the pixels. This approach necessitates a trade-off between brightness and contrast. If the display is blanked to a dark state, the average perceived brightness would decrease. If the display is blanked to a bright state, black pixels would appear bright for some of the frame time, increasing the perceived brightness of, and thereby decreasing contrast.

Temporal crosstalk also has undesirable effects in the field-sequential color mode of operation. Field sequential systems produce color images using a grayscale display and color illuminators (typically red, green, and blue). In this mode, a grayscale image corresponding to the red component of an image is drawn on the display and then the display is illuminated with a red light, from a light-emitting diode (LED) or with a bright lightbulb and a color filter. The process is repeated again for

BRIEF DESCRIPTION OF THE DRAWINGS

A more complete appreciation of the invention and many of the attendant advantages thereof will be readily obtained as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings, wherein:

Figs. 1a and 1b illustrates a graphic representation of a conventional system;

Fig. 2 illustrates a timing diagram according to an embodiment of the present invention;

Fig. 3 illustrates another embodiment of the present invention;

Fig. 4 illustrates an embodiment of the present invention;

Fig. 5 illustrates a timing diagram according to an embodiment of the present invention;

Fig. 6 illustrates another embodiment of the present invention; and

Fig. 7 illustrates a timing diagram according to another embodiment of the present invention.

DETAILED DESCRIPTION

The present invention relates to liquid crystal displays. In particular, the present invention relates to methods and apparatus for enhancing performance in liquid crystal displays.

Figs. 1a and 1b illustrates a graphic representation of a conventional system. As illustrated the pixels on an LCD, or other type of display, are illustrated driven with data signals in the first millisecond. Other terms for driven include drawn, painted, and the like. Typically, the pixels are driven from right to left within a row of pixels, and from top row to bottom row. Thus, the top left pixel is drawn first near the 0 millisecond mark, and the bottom right pixel is drawn last right before the 1 millisecond mark.

Fig. 1b illustrates typical physical characteristics of an LCD pixel. Fig. 1b illustrates the change in reflectivity of the pixel with respect to time. In this embodiment, when a drive voltage is applied so that the pixel becomes more reflective, brighter, the pixel takes at least a time 100 to brighten up. In this case, time 100 represents the amount of time for the pixel to change from 10% reflectivity

to 90% reflectivity. In typical embodiments, time 100 is on the order of 3.5 milliseconds

Further, in this embodiment, when a drive voltage is applied so that the pixel becomes more less reflective, darker the pixel takes at least a time 110 to
 5 darken. In this case, time 110 represents the amount of time for the pixel to change from 90% reflectivity to 10% reflectivity. In typical embodiments, time 110 is on the order of 1.5 milliseconds. As illustrated in Fig. 1b, time 100 and 110 are asymmetric.

In the embodiment in Fig. 1a, if the bottom right pixel is painted to be a dark pixel, the amount of time for the pixel to switch to dark is thus on the order of
 10 time 100, or in this example 1.5 milliseconds. Further, if the bottom right pixel is painted to be a bright pixel, the amount of time for the pixel to switch to bright is thus on the order of time 110, or in this example 3.5 milliseconds.

As illustrated in Fig. 1a, the worse case situation is where the last pixel is to be switched to bright. Because, it is not known a prior whether the last pixel is to
 15 be bright or dark, the worse case situation is assumed. Accordingly, only after approximately 4.5 milliseconds (1 milliseconds painting + 3.5 milliseconds waiting) is the correct data displayed on the entire LCD. After the data is correct, the entire LCD is illuminated.

Fig. 2 illustrates a timing diagram according to an embodiment of the
 20 present invention. In this example, all of the pixels of the LCD are drawn within 1 millisecond, as was described above. Further, the transition times from bright to dark and from dark to bright are also similar as described above.

The present embodiment includes an initialization or clear time 200, that is on the order of approximately .1 milliseconds. During this clear time 200, a
 25 transition optimized voltage is supplied to each of the pixels in the LCD to "initialize" the pixels. The transition enhanced voltage is supplied to each pixel until the pixel is driven with the "regular" data, during the 1 millisecond painting or drawing time.

For example, in the diagram in Fig. 2, during the clear time 200, a transition enhanced voltage associated with bright is supplied to all the pixels in the
 30 LCD, such as 5 volts. During the next 1 millisecond, driving voltages are supplied to all the pixels in the LCD. These driving voltages overwrite the transition enhanced voltage and may force the pixel to be dark, by applying 0 volts, or may force the pixel to be bright by applying 5 volts.

same voltage value then the column must be intact. Otherwise, a mismatch may indicate a defective column.

A second testing example occurs during the optical test of an assembled LCOS display. Since the entire image can be easily set by FlashVal to any
 5 desired voltage, intensity variations across the display at different FlashVals may be traced to physical device non-uniformity rather than temporal fading effects, or the like.

Fig. 6 illustrates another embodiment of the present invention. This embodiment includes a conventional active matrix array, however with the feature
 10 that the entire horizontal and vertical scanning registers can be configured to enable all column and row switches respectively.

Fig. 7 illustrates a timing diagram according to another embodiment of the present invention. This method applies a transition enhancement voltage, (transition bias voltage, or the like) to the pixels on the display, however at a slower
 15 rate than that illustrated in Figs. 4 and 5. In particular, the present invention asserts all row enable and column enable signals by the slower process of filling the vertical and horizontal scan registers with enable signals.

As illustrated, at the start of the field 600, the VINIT signal is asserted and VCLK is clocked once for each row (600 rows or lines in this case). VINIT is
 20 then unasserted. This operation loads a logical "one" into each element of the scanning register. The same operation is initiated at the same time for the horizontal scan register, with HINIT and HCLK respectively. In this example, HCLK is clocked once for each column (200 times in this example).

In this embodiment, the appropriate VTB voltage is driven onto the
 25 video channel signals (VIDEO 1-4) at the start of the operation. In an alternative embodiment, VTB may be driven at the completion of the register loading, however, asserting VTB at the beginning has the effect of reducing peak current through the video wires.

The result of the above invention is a new generation of higher
 30 performance liquid crystal displays. Many applications and modifications to this technology are envisioned. For example, global set and reset circuitry could be added to the vertical scanning registers instead of the "global row enable" circuit described above. Similarly, a global reset signal can be added to the horizontal scanning register to eliminate the scanning-out phase of the LineClear mode of operation. A

global column switch signal can also be used to disconnect the columns from the video lines instead of manipulating the horizontal shift registers.

One idea common to all of the above embodiments is that there should be some mechanism to quickly write particular voltages to all pixels on the display.

5 Further, a common idea to the LineClear mode of operation is the use of the video data channel to provide the transition bias voltage. The LineClear is somewhat of a misnaming, as it can be modified to address the entire array at once and equal the speed of the ArrayClear circuit.

10 In other embodiments, the switching circuit may be positioned at the "top" of the column switches. Further, , if there are other means for testing the pixel array, and if the video signal inputs can be easily driven to the transition bias voltages, this mode requires less circuitry and will therefore have better yield.

15 In embodiments of the present invention, the voltage applied to the pixel electrodes is not necessarily the full-brightness voltage. In most cases an intermediate voltage results in an acceptable image. This occurs because as the last pixel is written, if it is already driven too bright, it may take longer to switch back to the dark state. In some embodiments, the clearing circuitry should allow a range of analog values to be placed on the pixel electrodes as the transition bias voltage (VTB).

20 In situation where the frame rate is sufficiently high, the above techniques method still be applied. For example, the present embodiments allow more time for pixels to complete transitions, thereby improving color accuracy.

25 Further details regarding characteristics of one embodiment of the present invention is found in MD800G6 Preliminary Specifications in the attached appendix. This Specification is incorporated by reference for all purposes.

30 Embodiments of these circuits can be comprised of either discrete components as part of the display drive electronics, or in the other extreme can be completely integrated within the display substrate, or they can be comprised of any combination level of integration. A flat panel display may incorporate the LCD display and any of the above control circuitry.

The foregoing description of preferred embodiments of the present invention has been provided for the purposes of illustration and description. It is not intended to be exhaustive or to limit the invention to the precise forms disclosed.

The embodiments were chosen and described in order to best explain the principles of the invention and its practical application, thereby enabling others skilled in the art to understand the invention for various embodiments and with various modifications as are suited to the particular use contemplated. It is intended that the scope of the invention be defined by the following claims and their equivalents.